Fall 2006

Center for Micro and Nano Technology Newsletter

LLNL Engineering Directorate

Highlights of the CMNT facility

CMNT's state-of-the-art fabrication facility has the equipment and infrastructure needed for lithography, etching, diffusion, wafer bonding, and thin-film deposition and vacuum techniques such as metal evaporation and sputtering, plasma enhanced chemical vapor deposition (PECVD), and low-pressure chemical vapor deposition (LPCVD). The facility houses over 6000 square feet of Class 10–1000 clean rooms for micromachining, silicon microelectronics, III–V semiconductor optoelectronics, and guided-wave photonics.

Associated labs provide material characterization and device-testing capabilities, microscopic inspection, packaging, and electrical and optical testing of devices, and digital particle image velocimetry (DPIV). Additionally, the facility will be welcoming laser pantography capabilities in FY07.

The facility supports the following four material systems:

- Silicon and silicon compounds for microstructures and microelectro-mechanical systems applications.
- Glass for microfluidics and bio applications.
- Gallium-arsenide for photonics applications.
- Polymeric systems, such as polydimethylsiloxane (PDMS), polyimide, and SU-8, for microfluidics and biological applications.

Additionally, the CMNT facility has a packaging group dedicated to design, fabrication, and integration of customized microfabricated components into customer platforms.

Lawrence Livermore National Laboratory

Greetings from the CMNT!

Anantha Krishnan, Director of Research & Development

At Lawrence Livermore National Laboratory's Center for Micro and Nano Technology (CMNT), our objective is to invent, develop, and apply micro- and nanotechnologies in support of Laboratory missions. This newsletter offers a brief glimpse of some of the CMNT's ongoing technical projects as well as recent highlights in terms of patents, publications, projects, and seminars.

Key advancements over the last three decades in micro- and nanotechnology have enabled revolutionary growth in microelectronics and sensors in the commercial arena. The CMNT has been a leader in fueling this commercial growth while simultaneously customizing the same technologies for unique, noncommercial applications that are mission-specific to LLNL and DOE. The combination of the CMNT's world class R&D talent and unique fabrication facilities have enabled highly innovative and custom solutions to technology needs in the areas of stockpile monitoring and stewardship, homeland security, energy exploration, healthcare, and space exploration.

Work at the CMNT focuses on device development, system integration, and platform technology that bring together researchers and technologies from diverse disciplines such as engineering, chemistry, biology, physics, material science, and computer science. This multidisciplinary collaboration has led to novel capabilities in highly integrated bio-microsystems (for sensors and medical devices), photonic microsystems (for high- speed signal and data acquisition), micro-electromechanical systems (MEMS; for advanced sensing and actuation), and scalable power systems (for powering micro- and mesoscale devices).

The scientists and engineers at the CMNT are collaboratively involved in several leading edge R&D projects that are aimed at providing novel capabilities to support the national security infrastructure.

The heart of the CMNT. The Center consists of multidisciplinary scientists and engineers as well as technicians and support staff.

Department of Energy's Artificial Retina Program – Restoring Sight to the Blind

Dr. Satinderpall Pannu

Vision involves a complex process requiring communication among millions of cells between the human eye and brain. When light enters the eye, nearly 127 million photoreceptors in the retina initiate a series of electrical signals that ultimately become vision. A breakdown in this light-conversion process can lead to vision impairment or loss of sight. Two common diseases that damage the photoreceptors but leave the optic nerve and associated connections to the brain intact are age-related macular degeneration and retinitis pigmentosa. Currently, 6 million people in the U.S. and 25 million worldwide suffer from vision loss due to these two diseases. The number of people living with these afflictions is expected to double by 2020.

A team of LLNL engineers led by Dr. Satinderpall Pannu is participating in a national effort to develop a technology that would help restore sight to those left blind from the loss of photoreceptor function. A retinal prosthesis would be attached to the retina and function as the photoreceptor layer that converts optical signals to the electrical signals that are transmitted to the optic nerve. The array would serve as the interface between an electronic imaging system and the retina, thereby providing the electrical stimulation normally generated by the photoreceptors. The goal is to develop a 4-millimeter-square microelectrode array with 240 electrodes.

A microelectrode array developed as a retinal prosthesis. The metal electrodes are embedded in silicone-based substrate. Since it is compliant and biocompatible, silicone is a promising material for the microelectrode array.

The Department of Energy's Office of Science has committed $9 million over three years to the Artificial Retina Program (ARP) as part of the department's medical applications technology program. Dr. Pannu's team is collaborating with colleagues from Oak Ridge, Argonne, Sandia, and Los Alamos national laboratories; the University of California (UC) at Santa Cruz; the University of Southern California's Doheny Eye Institute; North Carolina State University; and Second Sight, a private company that plans to commercialize the prosthetic device. The overall program is lead by Dr. Mark Humayan of the Doheny Eye Institute, a retinal surgeon and biomedical engineer. Dr. Humayan recently won the R&D 100 Inventor of the Year award for the Artificial Retina Program.

As part of the CMNT, Dr. Pannu and his team are applying their expertise in the area of microelectromechanical systems (MEMS), which integrates micrometer-size mechanical elements, sensors, actuators, and electronics through microfabrication technology. The CMNT's recent successes include developments in microfluidic devices, microsensor technology, and microfuel cells. The CMNT is also a leading center for polymer fabrication with the capability of micro-fabrication and assembly of a number of polymers.

The current microelectrode array is embedded in a silicone substrate. LLNL researchers have previously used silicone as a substrate for microfluidic devices that collect and identify biological pathogens such as proteins, viruses, and bacteria. Since it is a biocompatible material, recent LLNL efforts have focused on developing processes for embedding metal microelectrodes and electronics within the silicone for use in biomedical devices. The microelectrode array must be isolated from corrosive and electrically conductive body fluids. The compliant nature of silicone also allows the embedded microelectrodes to conform to the complex curvature of the retina. Surgeons at the Doheny Eye Institute have successfully implanted a prototype prosthetic device in a dog's eye. The objectives were to determine how well the device conformed to the retina, the mechanical effects of the device on the retina, and any biocompatibility issues. Scanned images using optical coherence tomography showed the conformity of the implanted array on the retina. Surgeons were pleased with the results. The device is designed to be epiretinal; that is, it will be placed on the upper surface of the retina inside the eye. The implant will overlap the center of the eye's visual field, which is the area affected in macular degeneration.

Dr. Pannu's team is also developing methods of integrating complementary metal oxide silicon (CMOS) electronics into the retinal prosthesis. The CMOS electronics send the electrical signals to the microelectrodes to stimulate the retina. The CMOS electronics must be integrated with the microelectrode array to reduce the overall size and complexity of the retinal prosthesis. Concurrently, LLNL is developing advanced ocular surgical tools which will allow surgeons to precisely place the microelectrode array on the retina with minimal tissue damage.

Overall, LLNL is focused on the current operational goal of producing a 240-microelectrode array. Significant progress has been made each year, and a commercially available retinal prosthesis is only a few years away. Clinical trials on the current generation retinal prosthesis are scheduled to begin next year.

LLNL is working on other potential applications for this technology. This technology can be used in cochlear implants, deep brain stimulators for Parkinson's disease, and spinal cord injuries. The use of polymer microfabrication techniques will enable neural implants with much higher densities of electrodes. The LLNL team is encouraged with the results of the research that may help to restore eyesight to blind persons and may revolutionize the treatment for many neurologically based illnesses.

A prototype polydimethylsiloxane (PDMS) array used in testing.

Meeting the Needs of Radiation Detection with Novel Structures and Materials

Dr. Rebecca W. Nikolic

The CMNT's expertise in fabricating nanometer- and micrometer-sized semiconductor structures can be exploited to customize detectors and sensors for homeland security efforts. One crucial area is the detection of illicit special nuclear materials. Because special nuclear materials emit gamma rays and neutrons, LLNL is pursuing innovative detectors tailored to both of these signatures.

For certain homeland security applications in the field, detectors must be inexpensive, robust, operate at ambient temperature, provide high efficiency, and potentially suitable for covert operations. Current detector technology is limited in its ability to meet these requirements. For example, high-performance gamma-ray detectors operate only at liquid-nitrogen temperature, which significantly encumbers field operations. Neutron detectors used in the field typically operate with vessels filled with high-pressure helium gas. These instruments are large, require high voltage, and are sensitive to vibration.

Applying microtechnology methods could revolutionize these radiation detection devices. The Laboratory Directed Research and Development (LDRD) Program is funding a team led by CMNT engineer Rebecca Nikolic and Tzu-Fang Wang of the Laboratory's Chemistry & Materials Science Directorate to demonstrate that microscale materials can be fabricated to produce a high-efficiency thermal neutron detector.

Thermal neutron detectors can operate at room temperature because certain elements undergo nuclear reactions that can be detected. Present day thermal neutron detectors operate using a 50-millimeter-diameter tube filled with high-pressure helium gas, and employ about 1000 volts. Thermal neutron detection efficiency of 70 percent is possible, although smaller instruments are used for field applications. In practice, these instuments' efficiency is reduced to less than 30 percent because of requirements relating to long-term stability. The LLNL team's device, called the Pillar Detector, promises to achieve more than twice the efficiency of conventional thermal neutron detectors used in the field without the field issues that challenge detectors using helium tubes.

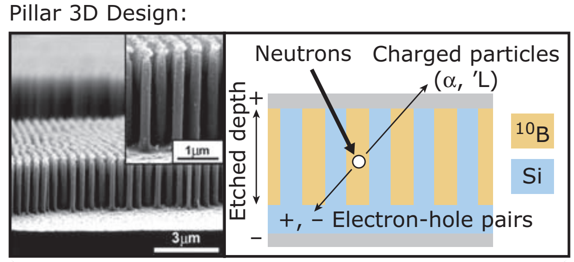
Instead of helium, the Pillar Detector relies on a carefully constructed platform of etched silicon pillars that are interspersed with boron, which serve to convert incoming neutrons to alpha particles. This 3-D structure maximizes the capture of neutrons. Incoming neutrons strike the boron nuclei, yielding alpha particles that interact with the semiconductor and induce the electrical current that is measured. Nikolic says, "We can adjust the pillar etch depth to provide a thicker boron layer for high neutron capture. We can also adjust the spacing between the pillars so the alpha particles don't have to travel far, which provides the device with high efficiency." The LLNL team is collaborating with Professor Barry Cheung from the University of Nebraska at Lincoln, who is assisting by depositing the boron layer of boron. The team anticipates that a prototype device will be ready before the end of 2006.

The CMNT is also contributing to the development and exploration of novel wide bandgap semiconductors for gamma detection. Within the CMNT, the microfabrication work is led by engineer Rebecca Nikolic, who is leveraging knowledge of semiconductor processing to help in the search for and development of the best material for detecting gamma rays at room temperature. An ongoing, multi-laboratory, DOE NA-22 effort to develop an aluminum antimonide gamma detector is one such project. Aluminum antimonide is particularly attractive for gamma detection because it offers a wide bandgap for room temperature operation, and a bandgap is indirect for enhanced carrier collection. The project is led by LLNL physicist Kuang Jen Wu, who is teaming with Paul Luke's group from Lawrence Berkeley National Laboratory (LBNL).

Together with LLNL physicist Steve Payne, the CMNT is exploring another prospective material with similarly attractive properties for gamma detection: gallium telluride. For both crystals, CMNT is developing processes for detector fabrication.

By applying microfabrication techniques to the areas of neutron and gamma detection, CMNT researchers are laying out pathways to improve the key figures of merit relating to radiation detectors.

Pillar 3D Design:



	^{3}HE Tube	Pillar Detector
Efficiency (fieldable)	< 30%	70%
Required voltage	1000 V	10 V
Size (probe)	(5ϕ) cm x 10 cm	1 x1 x 0.1 cm^3
Weight (includes power)	700 g	20 g
Fieldability	Microphonics, HV, air transport	Not commercial, similar cost/area

Comparison of standard helium-3 tubes for thermal neutron detection and LLNL's Pillar Detector design, which anticipates having high efficiency without penalties in fieldablity.

CMNT Researchers Develop "Nanobarcode" Particle-Based Biodetection Technology

Dr. George Dougherty

Engineers at the CMNT recently completed a project to explore novel methods for detecting biowarfare agents using functionalized metallic nanowire particles, or "Nanobarcodes." The work was done in collaboration with colleagues in the CMS Directorate's Biosecurity and Nanosciences Laboratory, commercial partner Oxonica Inc. (formerly Nanoplex Technologies, Inc.), Stanford University, and the UC Davis Center for Biophotonic Science and Technology. An article covering a portion of this work has recently been featured on the cover of the journal *Angewandte Chemie*.

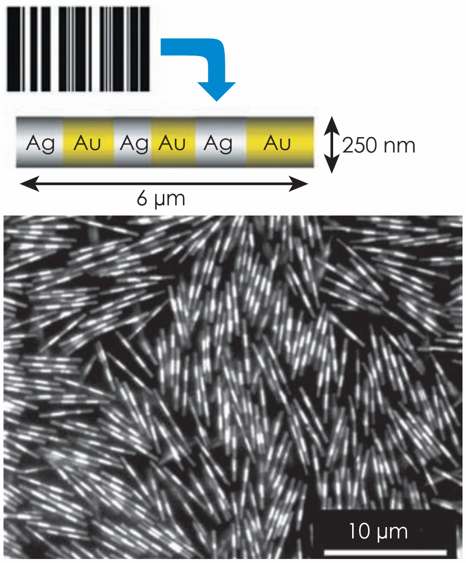
Enhanced biodetection systems are needed for biodefense applications such as deployable sensors to screen air for biowarfare or bioterrorism agents, and for medical applications such as clinical infectious disease diagnostics. Lawrence Livermore National Laboratory is a leader in the development of integrated biodetection technologies, such as the Autonomous Pathogen Detection System (APDS). APDS, developed here at LLNL for airborne pathogen surveillance, has been the subject of numerous press articles and is undergoing advanced field testing in a number of major U.S. cities.

LLNL's LDRD Program funding, the Engineering Directorate, and the Nonproliferation, Homeland and International Security (NHI) Directorate have a joint three-year nanobarcode project to investigate new approaches that could enable further advancements in the state of the art for fielded biodetection systems. In particular, evolving requirements call for high degrees of multiplexing (simultaneous tests for many pathogens on the same sample), very compact and portable devices, and automated sample processing.

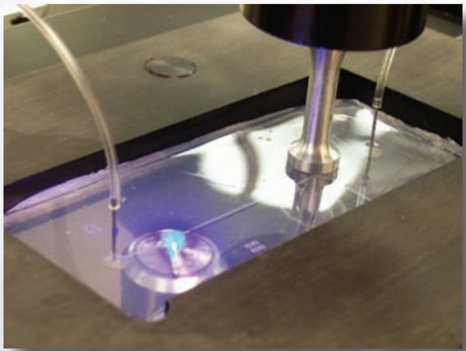
Led by CMNT researcher George Dougherty, the approach of the research was to use striped metallic nanowire particles as the substrates for a fluorescent immunoassay. The Nanobarcodes® Particles developed by Oxonica, Inc. are ideal for this application. The particles are made by depositing layers of gold and silver metal in a porous alumina membrane having very small parallel through-holes. When the template is dissolved away, the particles become free-floating nanowires with a unique pattern of light and dark stripes that can be read optically, like a supermarket barcode. Each set of uniquely striped particles is functionalized with antibodies specific to a different pathogen of interest. When a mixture of such nanobarcode particles is mixed with a suspect sample, the particles carrying antibodies against a particular pathogen in the sample will bind with it, and this binding event can be seen by subsequently adding antibodies labeled with fluorescent tag molecules. An automated microscopy image processing system can observe the particles, using the striping patterns to identify each one and fluorescence detection to determine whether it has detected its target pathogen in the sample.

While the particles are small (about 250 nanometers in diameter and a few micrometers in length), the number of unique striping patterns they can potentially carry number in the hundreds or even thousands. Dr. Jeffrey Tok of LLNL's Biosecurity and Nanosciences Laboratory (BSNL) led the effort to develop a multiplex assay for biowarfare agent simulants using the particles, resulting in a working demonstration assay that can detect Bacillus globigii (bacterial spore), MS2 (virus), and ovalbumin (toxin simulant). The targets that can be detected are limited only by the antibodies or alternative detection ligands that are available for functionalizing the particles.

The project also investigated ways to transport and manipulate the particles using electromagnetic fields; studies of particle properties and behavior aqueous solutions, including the effects of different surface coatings and proteins; and the development of a benchtop prototype system to carry out automated nanowire-based assays within microfluidic cards. The electromagnetic transport study, performed by CMNT engineer Dr. Klint Rose, developed techniques for magnetically transporting the particles by integrating nanoscale magnetic segments within the nanowire particles, and rotating and aligning them using oscillating electric fields. These advances led to implementing the nanowire particle-based immunoassay on an automated computer-controlled microfluidic platform, using an external electromagnet and an ultrasonic transducer to capture and resuspend the particles during sample processing steps. The results were read using an image processing system attached to a standard epifluorescent microscope. The details and results of these studies are the subject of additional upcoming journal articles.



Up to a billion Nanobarcodes® Particles, with identical barcode striping patterns, are produced from a single anodic alumina membrane. The particles bear striping patterns analogous to supermarket barcodes, allowing a very high level of multiplexing.



In use, the microfluidic card is connected to an automated fluidic system and interfaces with an epifluorescent microscope, an ultrasonic transducer, and a compact electromagnet (hidden beneath the card in this image).

Recent Highlights

Publications

C. M. Spadaccini, J. Peck, and I. A. Waitz, *in press,* "Catalytic Combustion Systems for Micro Gas Turbine Engines", *ASME Journal of Engineering for Gas Turbines and Power,* GTP-05-1009, 2006.

Book Chapter: C. M. Spadaccini and I. A. Waitz, *in press,* "Emerging topics: Microcombustion", in Y. Gianchandani, O. Tabata, and H. Zappe, *Comprehensive Microsystems,* Elsevier, 2007.

C. L. Cheung, R. J. Nikolic, C.E. Reinhardt, and T.F. Wang, "Fabrication of Nanopillars by Nanosphere Lithography," *Nanotechnology,* **Vol. 17,** pp. 1339-1343, March 2006.

H. G. Park, J. A. Malen, W. T. Piggott III, J. D. Morse, R. Greif, and C. P. Grigoropoulos, "Methanol Steam Reformer on a Silicon Wafer," *JMEMS,* 2006.

R. J. Welty, T. C. Bond, E. Behymer, G. Loomis, J. Wolfe, S. Vernon, M. Pocha, "Integrated Laser with Low-Loss High Index-Contrast Waveguides for OEICs," *Photonics West, SPIE,* San Jose, CA, January 2005.

M. Pocha, T. C. Bond, J. Kallman, G. Khanaka, R. Welty, E. Behymer, S. Vernon, "Gain Lever Characterization in Monolithically Integrated Diode Lasers," *Photonics West, Proceedings of the SPIE,* San Jose, CA, January 2005.

J. Kotovsky, "MEMS Contact Stress Sensing," Ph.D. thesis.

L. Goddard, "Characterization and Modeling of the Intrinsic Properties of 1.5 µm GaInNAsSb/GaAs Lasers," Ph.D. thesis, March 2005.

L. Goddard, S. Bank, M. Wistey, H. Yuen, Z. Rao, and J. S. Harris Jr., "Recombination, Gain, Band Structure, Efficiency, and Reliability of 1.5-µm GaInNAsSb/GaAs Lasers," *J. Appl. Phys.,* **97,** pp. 083101-1-15, April 2005.

S. Bank, L. Goddard, M. Wistey, H. Yuen, and J. S. Harris Jr., "On the Temperature Sensitivity of 1.5-µm GaInNAsSb Lasers," *J. Sel. Topics Quantum Electron.,* **11,** (5), pp. 1089-1098, September 2005.

S. Bank, H. Bae, H. Yuen, M. Wistey, L. Goddard, and J. S. Harris Jr., "Room-Temperature Continuous-Wave 1.55 µm GaInNAsSb Lasers on GaAs," *Electron. Lett.,* **42,** (3), pp. 156-7, February 2006.

M. Wistey, S. Bank, H. Bae, H. Yuen, E. Pickett, L. Goddard, and J. S. Harris, "GaInNAsSb/GaAs Vertical Cavity Surface Emitting Lasers at 1534 nm," *Electron. Lett.,* **42,** (5), pp. 282-3, March 2006.

J. V. Candy, D. S. Clague, and J. W. Tringe, "A Model-Based Processor Design for Smart Microsensor Arrays," *IEEE,* 2006.

J. W. Tringe, D. S. Clague, J. V. Candy, A. K. Sinensky, C. L. Lee, R. E. Rudd, and A. K. Burnham, "Model-based Processing of Microcantilever Sensor Arrays," *JMEMS,* 2006.

J. B.-H. Tok, F. Y. S. Chuang, M. C. Kao, K.A. Rose, S. S. Pannu, M. Y. Sha, G. Chakarova, S. G. Penn, and G. M. Dougherty, "Metallic Striped Nanowires as Multiplexed Immunoassay Platforms for Pathogen Detection," *Angewandte Chemie*, 2006.

Projects

R. J. Nikolic, "Study of Transport Behavior and Conversion Efficiency in Pillar Structured Neutron Detectors" (Engineering LDRD).

R. Nikolic, "Aluminum Antimonide Detector" (NA-22).

R. Nikolic, "Pillar Structured Radiation Detector" (Engineering Tech Base).

C. V. Bennett, "Ultra-fast Chirped Waveform Detector" (DARPA).

C. V. Bennett, "Ultra-fast Transient Recorder" (Engineering Tech Base).

K. D. Ness, "Thermal-Fluidic System for Manipulating Biomolecules and Viruses" (Engineering LDRD).

G. M. Dougherty, "Automated/Integrated Sample Preparation for Biosensor Systems" (DARPA).

G. M. Dougherty, "Engineered Aerosol Production for Laboratory-Scale Chemical/Biological Test and Evaluation" (DTRA).

R. P. Mariella, "Rapid Defense Against The Next-Generation Biothreat" (Engineering LDRD).

J. E. Heebner, "Evaluation of Ultra fast Recording Technologies for Reduction to Practice" (Engineering Tech Base).

L. Brewer, "Single Molecule Assay of DNA Integrity" (Engineering Tech Base).

M. D. Pocha, "Absolute Conditioner for Fabry-Perot Microsensors" (Engineering Tech Base).

J. C. Davidson, "Block Copolymer Nanolithography" (Engineering Tech Base).

D. S. Clague, "Predictive Design Capability for Nanoscale Manufacture using Block Copolymers" (Engineering Tech Base).

R. R. Miles, "Silicon Nitride Furnace – Installation and Characterization" (Engineering Tech Base).

K. A. Rose, "Precision Sample Control and Extraction Component for Micro-Fluidic Instrumentation" (Engineering Tech Base).

C. M. Spadaccini, "Grayscale Lithography" (Engineering Tech Base).

A. P. Papavasiliou, "Co-location of MEMS and Electronics" (Engineering Tech Base).

R. R. Miles, "Virtual Window for Long IR Wavelength Biological Characterization" (DOE/OBER/LBNL).

S. S. Pannu, "Artificial Retina Program – Restoring Site to the Blind" (DOE/OBER/USC).

J. D. Morse, "High Sensitivity Field Probe" (NA-22).

J. D. Morse, "Compact High Intensity Crystal Driven Neutron Source" (Engineering LDRD).

Recent Highlights (continued)

Patents

Vapor-Deposited Porous Films for Energy Conversion
U.S. Patent 6,913,998 B2 (July 5, 2005)
Alan F. Jankowski, Jeffrey P. Hayes, Jeffrey D. Morse

Bonded Polyimide Fuel Cell Package and Method Thereof
U.S. Patent 6,960,403 B2 (November 1, 2005)
Jeffrey D. Morse, Alan Jankowski

Chemical Microreactor and Method Thereof
U.S. Patent 6,960,235 B2 (November 1, 2005)
Jeffrey D. Morse, Alan Jankowski, Robert T. Graff, Kerry Bettencourt

Microfluidic Fuel Cell Systems with Embedded Materials and Structures and Method Thereof
U.S. Patent 6,921,603 B2 (July 26, 2005)
Jeffrey D. Morse, Klint A. Rose, Mariam Maghribi, William Benett, Peter Krulevitch, Julie Hamilton, Robert T. Graff, Alan Jankowski

Direct-Patterned Optical Waveguides on Amorphous Silicon Films
U.S. Patent 6,925,216 B2 (August 2, 2005)
Steve Vernon, Tiziana C. Bond, Steven W. Bond, Michael D. Pocha, Stefan Hau-Riege

High Stroke Pixel for a Deformable Mirror
U.S. Patent 6,947,188 B2 (September 20, 2005)
Robin R. Miles, Alexandros P. Papavasiliou

Method for Detecting Pathogens Attached to Specific Antibodies
U.S. Patent 6,846,639 B2 (January 25, 2005)
Robin R. Miles, Kodumudi S. Venkateswaran, Christopher K. Fuller

Stepped Electrophoresis for Movement and Concentration of DNA
U.S. Patent 6,866,759 B2 (March 15, 2005)
Robin R. Miles, Amy Wei-Yun Wang, Raymond P. Mariella, Jr.

Integrated Electrical Connector
U.S. Patent 6,897,557 B2 (May 24, 2005)
William J. Benett, Harold D. Ackler

PCR Thermocycler
U.S. Patent 6,893,863 B2 (May 17, 2005)
William J. Benett, James B. Richards

Electronic Unit Integrated into a Flexible Polymer Body
U.S. Patent 6,878,643 B2 (April 12, 2005)
Peter A. Krulevitch, Mariam N. Maghribi, William J. Benett, Julie K. Hamilton, Klint A. Rose, James Courtney Davidson, Mark S. Strauch

Electronic Unit Integrated into a Flexible Polymer Body
U.S. Patent 6,991,963 B2 (January 31, 2006)
Peter A. Krulevitch, Mariam N. Maghribi, William J. Benett, Julie K. Hamilton, Klint A. Rose, James Courtney Davidson, Mark S. Strauch

Amphiphilic Mediated Sample Preparation for Micro-Flow Cytometry
U.S. Patent 7,081,227 (July 25, 2006)
David S. Clague, Elizabeth K. Wheeler and Abraham Lee

Rapidly Reconfigurable All-Optical Universal Logic Gate
Provisional Patent Application (May 2006)
Lynford Goddard, Tiziana C. Bond, and Jeffrey Kallman

Seminars/Visitors

Jessica Melin, Ph.D., Director of Stanford Microfluidics Foundry, Research Associate, "Biological Large Scale Integration & Stanford Microfluidics Foundry" (April 2006).

Prof. M. Muthukumar, University of Massachusetts, "Nanofabrication with Polymers: Intelligent Design of Competition" (April 2006).

Piotr Grodzinski, Ph.D., Program Director, NCI Nanotechnology Alliance, "National Cancer Institute Cancer Nanotechnology: An Opportunity for a New Class of Diagnostic and Therapeutic Solutions" (April 2006).

Ken Babcock Ph.D., Innovative Micro Technology and Affinity Biosensors, Santa Barbara, CA, "Biomolecular Detection with Microchannel Resonators" (May 2006).

Sergey Ermakov Ph.D., Applied Biosystems, "Microfluidics and DNA Analysis" (May 2006).

Prof. Chang Liu, University of Illinois, "Micro Technology Research for Bioinspired Sensing and Top-down Nanotechnology" (May 2006).

Prof. Ming Wu, UC Berkeley, "Optical/Electrical Techniques from Droplet Manipulation in Microfluidic Devices" (July 2006).

Cristina Davis, Ph.D., Assistant Professor in Mechanical and Aeronautical Engineering, University of California, Davis; Microfabricated Sensors for Biodefense and Clinical Diagnostics Applications (July 2006).

Alec Talin Ph.D., Sandia National Laboratories, Livermore, "Nanostructure Based Electronics, Photonics, and Sensors" (August 2006).

Anthony F. J. Levi, Professor, University of Southern California; Frontiers in Device Engineering: Synthesis for Quantum Systems (August 2006).

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